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IN HYDROGEN, BY PROFESSOR J. C. McLENNAN AND H. N.
MERCER

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On the Ionisation Tracks of Alpha Rays in Hydrogen.

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(Read May Meeting, 1915).

I. INTRODUCTION.

In a paper by Marsden in the *Phil. Mag.* of May, 1914, experiments are described in which it was found that when alpha particles from radium are projected into hydrogen velocities are given to particles of the gas which enable them to pass through a thickness of aluminium foil capable of stopping the fastest alpha particles. These "H" particles, as Marsden designated them, have been shown by him to be capable of producing visible scintillations on a zinc sulphide screen when this is placed at a distance away from their source more than three times the distance at which the alpha particles themselves produce scintillations.

On account of the high velocities possessed by these "H" particles and for various other reasons it is believed that they are the positively charged nuclei of hydrogen atoms just as alpha particles are the charged nuclei of helium atoms and that they are expelled from the atoms of hydrogen when these are subjected to a direct impact by the alpha rays.

Moreover since these "H" particles are capable of producing scintillations in a zinc sulphide screen and since scintillations are now considered to be the results of ionisation it would appear that these "H" particles are capable of ionising the atoms in the zinc sulphide. The question, then, which naturally arises is: Are these "H" particles capable of ionising the atoms of a gas through which they may be projected? In order to throw some light on this matter it was thought well by the writers to make an experimental study of the ionisation tracks of alpha rays in hydrogen and the following paper contains an account of this investigation.

II. APPARATUS.

The method followed was precisely the same as that devised by C.T.R. Wilson¹ and used by him in obtaining his exceedingly beautiful

¹ C. T. R. Wilson, *Proc. Roy. Soc. A* Vol. 87, pp. 277-292, 1912.

ionisation tracks of alpha, beta and X-ray tracks in air. The apparatus which was made by the Cambridge Scientific Instrument Co. under his direction is shown in Fig. 1., and in diagram in Fig. 2. For

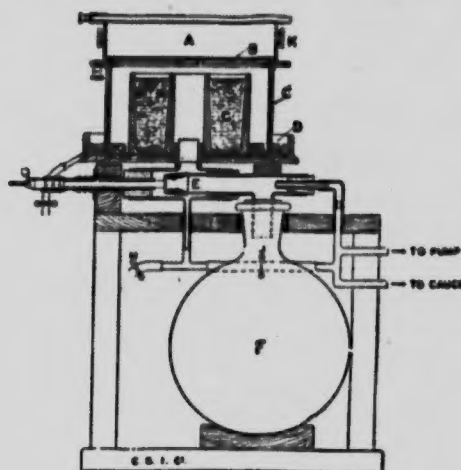


Fig. 2.

complete details of the construction and operation of this apparatus the reader is referred to C. T. R. Wilson's original paper¹ or to the descriptive catalogue of the Cambridge Scientific Instrument Co. It will suffice here to say that the cylindrical cloud chamber A. Fig. 2 was about 16.5 cms in diameter and 3.4 cms in height. The walls and roof of this cloud chamber A were coated inside with gelatine containing a trace of copper sulphate and the plate glass roof, B, of the piston or plunger, C, was coated with gelatine blackened with ink and containing 2% of copper sulphate. The expansion was effected by opening the valve E and so connecting up the air space below the plunger with the evacuated chamber F. In all the experiments the apparatus was arranged so that the ratio of the final to the initial volume V_2/V_1 of the gas in the expansion chamber above the plunger was about 1.36 : 1.

As the plunger was always at the bottom of the chamber when the expansion was completed, the value of the ratio V_2/V_1 depended upon the height to which the plunger was raised initially. It was raised therefore to any height desired by simply removing the stopper K from the expansion chamber and blowing into the tube H. The reading taken on the gauge depicted in Fig. 1 after expansion showed when the proper ratio for V_2/V_1 was secured.

¹ *loc. cit.*

In order to obtain distinct ionisation tracks it was necessary to have all ions in the cloud chamber removed before the expansion took place and this was effected by establishing an electric field between the top plate of the plunger and the roof plate of the cloud chamber. To do this the gelatine layer under the roof plate was connected by means of a ring of tinfoil cemented between the glass cylindrical wall and the roof plate to one terminal of a battery of storage cells whose other terminal was connected to the metallic base of the expansion chamber and through the brass cylindrical portion of the plunger to the roof plate of the latter.

In taking the photographs the method followed was also that adopted by C. T. R. Wilson and consisted in passing the discharge from a set of Leyden jars charged with a Holtz machine through some vapourized mercury in a set of four quartz tubes joined in series and placed close to the walls of the expansion chamber. The light from these discharge tubes was projected into the expansion chamber in beams of parallel rays by a set of four plano-convex strips of glass. The camera was directed vertically down upon the roof plate of the cloud chamber. In setting up the apparatus it was found convenient to separate the vacuum chamber somewhat from the expansion chamber and the manner in which this was done is shown in the upper part of Fig. 3. In the lower part of the figure the connections are shown

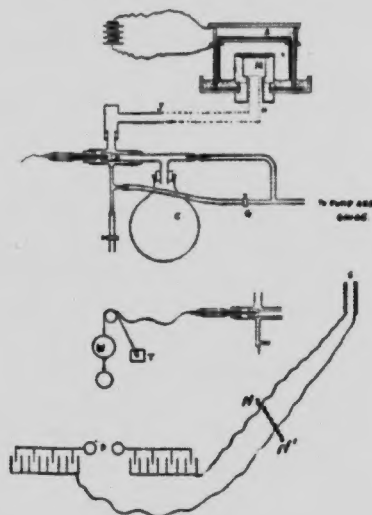


Fig. 3.

for producing the expansion and exciting the spark. The Holtz machine was joined to the insides of two sets of Leyden jars at P,

NN' was a wet string short circuiting the outsides of the jars and S represents the discharge tubes in which the secondary spark occurred. In taking the photographs the string joined to T, Fig. 3, was cut and the valve B was opened by the falling weight W. When this weight reached the limit of its fall a second weight in the form of a brass ball and supported by a slender cord broke away and fell between the terminals at P and brought on both the primary spark at P and the secondary discharge at S. The height of the brass ball from the spark gap, P, was adjusted so as to bring on the discharge at the instant desired after the expansion took place.

In the experiments carried out by us the cloud chamber above the plunger was filled either with air or hydrogen or with mixtures of air and hydrogen and the cloud tracks were formed by the condensation of either water vapour or the vapour of absolute alcohol.

The source of the alpha rays was a layer of polonium on the anterior face of a small sheet of copper of area about 1 sq. mm. This plate of copper was attached to a short stout copper wire which projected into the cloud chamber and was held in position by being fastened with wax to the stopper K, Fig. 2. When hydrogen was used the ionisation tracks in most cases extended completely across the cloud chamber. In the present investigation, however, it was the ends of the trails which were to be specially examined and so the tracks in hydrogen were cut down by covering the layer of polonium with sheets of very thin aluminium leaf. This was done in all the experiments in which the photographs of tracks in hydrogen were taken which are described in this paper. The lengths of the reduced tracks were generally about 4 cms. or less.

III. EXPERIMENTS.

Although the investigation was primarily directed to obtaining if possible evidence of the production and of the ionising power of the "H" particles of hydrogen and many photographs were taken with that end in view, not one of the photographs showed any trace of cloud tracks pointing to their production or to ionisation by them. Many of the tracks shewed abrupt bends similar to those obtained by Wilson and occasionally very short spurs were obtained at these bends, but no spurs were obtained such as one should expect to get with "H" particles travelling with velocities such as those Marsden found they possessed.

This absence of "H" particle cloud tracks in our experiments cannot be taken, however, to mean that "H" particles are not produced in hydrogen or that they do not possess the power to ionise a gas but it goes to confirm, rather, what has been already surmised that when

alpha rays traverse hydrogen exceedingly few of them, collide with the hydrogen atoms in such a way as to expel the "H" particles.

Although the experiments were disappointing in this regard they served to bring out some points of minor interest and a few of the photographs taken are reproduced in the present communication to illustrate these points. The photograph reproduced in Fig. 4 is one taken of water cloud-tracks of alpha rays in hydrogen and enlargements of portions of this photograph are shown in Figs. 5 and 6.

In Fig. 5 there is shown a sharp bend near the end of one of the tracks and a less abrupt one near the middle of a second track. Fig. 6 also shows a very sharp bend near the end of one track but as will be seen there is no sign of a spur of any appreciable length associated with it. The tracks shown in these photographs are typical of many which we obtained but as mentioned above none of them showed spurs such as we expected to get with expelled "H" particles. In taking the photograph shown in Fig. 4 a field of 70 volts was applied in the cloud chamber and a Zeiss Planar lens F 4.5, 5 cms focus was used. The photograph was taken on an Ilford Monarch plate.

The reproduction shown in Fig. 7 also shows a sharp bend in one of the tracks but there is no indication of any spur at the bend. It was obtained with hydrogen and condensed water vapour. The field applied to the cloud chamber was 8 volts.

Figs. 8, 9 and 10 are reproductions of enlargements of the ends of some alpha ray tracks in hydrogen the clouds of which were formed from water vapour. The field applied to the cloud chamber when they were taken was 8 volts. The interest in these photographs lies in the fact that the ends of the tracks and the curves they exhibit are somewhat more extended than those obtained by Wilson with air. In some cases it will be seen they resemble the curve at the end of a hockey stick while in others the bends are more like the ends of a shepherd's crook.

Some of the tracks shown in Fig. 8, as will be seen, appear to be double while others again are single and very distinct. The double tracks are clearly out of focus and more or less indistinct. From their general appearance the doubling would appear to be entirely an optical effect but it is just possible that it represents an electrical separation of the ions in those tracks which were produced a short time before the more distinct ones. Against this latter view, however, there is the fact that the separation shown on the photograph appears to be lateral while if it had been produced by the electrical field the displacement in all probability would have been in a vertical plane or very close to it.

The track in Fig. 11 and its enlargement in Fig. 12 was also obtained with hydrogen and water vapour the field applied being 30 volts. In this one the crook at the end is brought out very clearly as well as the abrupt bend at the middle. At this bend there is a slight protuberance or thickening on the convex side which looks something like a shortened spur but it is only just noticeable. Although photographs of many alpha tracks showing abrupt bends were taken this one represents practically the maximum indication of a spur which was obtained. This shows that if the "H" particles really do ionise a gas the kind of collision which results in the liberation of such particles is of exceedingly rare occurrence.

If the reproduction shown in Fig. 12 be closely examined it will be seen that in addition to the abrupt bend near the middle and the crook at the end there is a slight bend of double curvature between these two. Many of the tracks photographed showed this gradual change in curvature and it was thought at first that they constituted evidence opposed to the view advanced by Rutherford that the scattering of alpha particles of large amount is the result of single deflections through considerable angles and not to a cumulative effect due to a very large number of minute deviations. Continued investigation, however, showed that the bending mentioned above was mechanical in its origin and was due to a distortion impressed upon the track of ions in the gas by the irregular movement of the gas in the course of expansion after the alpha ray particle had passed but before the condensation actually took place. In some of the photographs the distortion of the alpha ray tracks was very considerable and an enlargement of one of a number which exhibited this in a very marked way is shown in Fig. 13. Here it will be seen the curvature commences practically at the beginning of the tracks and extends for a considerable distance over their length.

In this photograph the tracks were in hydrogen but the cloud was formed from the condensation of alcohol vapour. The field applied was 30 volts.

Fig. 14 exhibits another feature which characterised a number of the photographs. In this one it will be seen that a considerable space intervenes between the polonium plate and the commencement of the alpha ray tracks. In this particular photograph the ionisation was in hydrogen and the cloud was formed from alcohol vapour. Similar results were also obtained when the clouds were formed from water vapour. This absence of condensation at the beginning of the tracks was taken to mean that owing to the proximity of the copper plate carrying the polonium the gas in this region was kept sufficiently warm during the expansion to prevent condensation of the vapour.

IV. SUMMARY OF RESULTS.

1. It has been shown that although alpha ray tracks in hydrogen are of greater length than those in air they exhibit similar characteristics to those obtained in air.
2. It has been shown that alpha ray ionisation tracks can be exhibited by the condensation of alcohol vapour equally as well as with the condensation of water vapour.
3. The photographs obtained confirm the observation of C. T. R. Wilson and support the contention of Rutherford that apart from the crooks at the ends of the alpha ray tracks the "scattering" is due to single deflections through considerable angles.
4. The experiments failed to bring out evidence in support of ionisation by the nuclei of hydrogen atoms projected from the latter when alpha particles collide with the atoms.
5. The experiments go to show that when alpha particles are projected through hydrogen exceedingly few collisions occur which result in the ejection of a hydrogen nucleus.

The Physical Laboratory,
University of Toronto,
May 1st, 1915.

PLATE I.

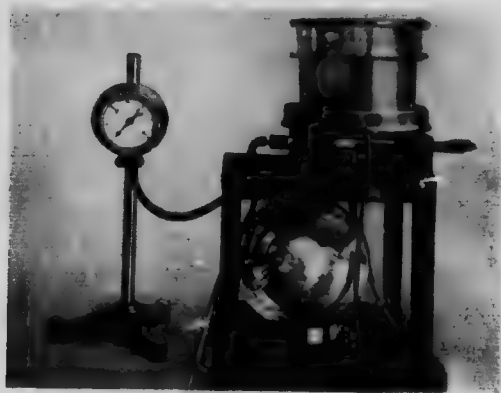


Fig. 1.



Fig. 4.

PLATE II.



Fig. 5.



Fig. 6.



Fig. 7.



Fig. 8.

PLATE IV.



Fig. 9.



Fig. 10.

PLATE V.



Fig. 11.

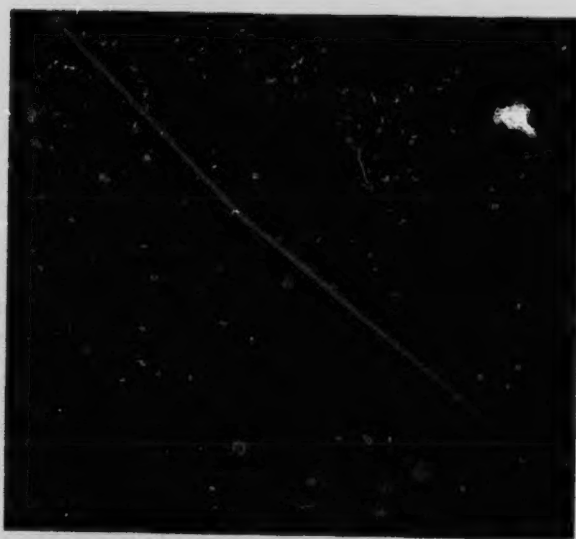


Fig. 12.

PLATE VI.



Fig. 13.



Fig. 14.